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| **Lesson Title: Mapping The Topography of Unknown Surfaces** |
| **Subject area / course / grade level: Science (4-8 grade)** |
| **Introduction:**  The *Viking* orbiters provided wonderful pictures, and subsequent imageprocessing created mosaics of most of Mars. But much important informationis still missing. An example is something as basic as the elevation of future landingsites. Because Mars’ atmosphere is so thin, parachutes are relatively lesseffective than here on Earth. (There’s less resistance to slow the spacecraftdown: Newton’s Laws, once more!) So, it’s critical to know how thick a layer ofMartian atmosphere you’re traveling through before you reach the surface. Ifthe landing sites are too high up, there’ll be too little atmosphere, and you maydesign a braking system that won’t work well enough to slow your descent!Ouch... back to the drawing board. Current uncertainties about Martian elevationsare as large as 3 kilometers, enough to make spacecraft designers very nervous.Enter “MOLA.”One of the six instruments on board Mars *Global Surveyor* will be the MarsOrbiter Laser Altimeter (MOLA). MOLA’s laser will fire pulses of infrared light10 times each second. By measuring the length of time it takes for the light toreflect off the Martian surface and return to the spacecraft, scientists can determinethe distance to the planet’s surface. (Spacecraft navigation data gives the distanceof *MGS* from the center of the planet, so putting the two data sets togetherwill yield Martian surface elevation with a precision of a few tens of meters.)MOLA will provide information to construct the first full topographic map ofMars, showing fine details of plains, valleys, craters and mountains.Note: Since topographic maps use sea level to define zero elevation, weEarthlings measure the height or depth of all landforms relative to sea level. Ofcourse there’s no sea on Mars, so scientists describe elevations relative to a zerolevel that is called the “datum” surface. |
| **Lesson Length: 3-5 hours** |
| **Materials: (for each team of 3/4 students)**   * 1 shoebox with lid * scissors * pencils * adhesive/scotch tape * metric ruler * 1 grid support constructed by gluing one complete 16 cm x 30 cm grid paper onto a piece of cardboard * Altimeter rod (10 cm length, cut from a coat hanger   or wooden skewer)   * an awl, leather punch or other sharp object to punch   holes in top of shoebox   * 7 sheets of cm grid paper (16 cm x 30 cm) * *papier mache*, plaster of paris, or small pieces of   rocks, wood, aluminum foil that can be used to make  a Martian terrain inside bottom of shoebox   * contour map of Olympus Mons and Valles Marineris |
| **Vocab:** altimeter, crater, datum surface, infrared, landform, laser, mountain, plain, probe, pulse, radar, simulate, sonar, terrain, topographic map, valley |
| **Tennessee Standards:**   * **GLE 0507.6.1** Compare planets based on their known characteristics. * **GLE 0507.Inq.2** Select and use appropriate tools and simple equipment to conduct an investigation. * **GLE 0507.Inq.3** Organize data into appropriate tables, graphs, drawings, or diagrams. * **GLE 0507.Inq.6** Compare the results of an investigation with what scientists already accept about this question. * **GLE 0507.T/E.1** Describe how tools, technology, and inventions help to answer questions and solve problems. * **GLE 0507.T/E.4** Recognize the connection between scientific advances, new knowledge, and the availability of new tools and technologies. * **GLE 0607.Inq.2** Use appropriate tools and techniques to gather, organize, analyze, and interpret data. * **GLE 0607.Inq.3** Synthesize information to determine cause and effect relationships between evidence and explanations. * **GLE 0607.Inq.4** Recognize possible sources of bias and error, alternative explanations, and questions for further exploration. * **GLE 0607.Inq.5** Communicate scientific understanding using descriptions, explanations, and models. * **GLE 0607.T/E.2** Know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting. |
| **Lesson objective(s):**   1. Students will be able to describe in words and graphic displays the elevation or depression profile of sections of Mars’ Olympus Mons and/or Valles Marineris. 2. Students will demonstrate the ability to describe the operation of the *MGS* laser altimeter, and simulate its operation. 3. Students will be able to explain how orbiting spacecraft build up global maps one data slice at a time. 4. Students will use contour maps to create 3-dimensional Martian landforms. 5. Students will transform numerical measurements into 3-D representations of hidden landforms. |
| **ENGAGEMENT:**  Explain why NASA needs elevation data from Mars, and how MOLA operates, or have teams go on-line and research MOLA and report back. As noted above, the altitude of a landing site can be crucial for spacecraft safety. Tell students that they represent a NASA Mission team specializing in mapping the elevation of a little known planet. This Activity simulates the process of gathering data about a surface which can’t be measured directly. Working in teams, students will first construct a segment of Mars—in 3 dimensions—from current contour maps, without revealing its exact topography to other teams. This Challenge landscape will be hidden inside a securely closed shoebox. Each team, in turn, will receive a Challenge landscape created by another team, and unknown to them. Their mission is to collect simulated altimeter data on the Challenge landscape, and create a 3-D paper profile map of what they think is hidden in the box (the “Result” landscape). At the end of the Activity, they’ll see how accurately Challenge and Result landscapes match. Note: Ideally, this is a two stage Activity: you can do just the measuring activity, but the students will benefit both from creating the Challenge and Result landscapes (scaling, plotting, cooperation and model making skills) which will let them literally get their hands on two sections of Mars. |
| **EXPLORATION:**  **Making the Challenge Landscape**   1. Working from the sections of contour maps you provide, each   team should make a three-dimensional Mars landscape covering  the bottom of the shoebox.   1. Tape or glue a piece of cm grid paper to box lid. Label horizontal   and vertical axis 0, 1, 2, 3, etc.   1. Using a sharpened awl or leather punch, punch small holes at   intersections of the grid. Be careful!   1. Seal box with tape. Exchange the closed Martian   Challenge boxes.  **Altimeter Simulation**  Tell students that they will now simulate the Mars Orbital Laser Altimeter using the “Altimeter rod” and collect data representing the Mars terrain hidden in the shoebox.  The teacher might want to demonstrate the following procedure:  1. Find the coordinates (0,0) on the box top.  2. Insert the Altimeter rod into the hole at (0,0), until it comes in contact with the landform inside.  3. Keeping the rod upright, measure how much is showing above the lid. Subtract this from its full 10 cm. length to find the distance from “orbit” (lid) to surface (or use a piece of easily removable paper tape as a marker, and remove and measure the rod.)  4. On the graph paper plotting grid, locate the (0,0) coordinate and count down the number of centimeters which the rod measured. Plot this point on the grid.  5. Repeat this procedure across the row (0,1), (0,2) (0,3), (0,4), etc. to (0,30).  6. Connect the altimeter readings across the row.  7. Cut along this data line.  8. Fold along the dotted line (row 10) and glue on the appropriate row (0,0 for the example above) of the grid support. You now have the first row of your three dimensional Mars landscape.  (See Diagram)  contour map |
| **EXPLANATION:**  Note: to move things along, in a team of 3-4 students, one might be MOLA and collect and measure altitude, one might plot the data points, and another might cut out and assemble the profile sheet once each row of data has been collected. Students should rotate through tasks to expose each of them to all parts of the process.  Repeat this procedure for:   * the second row, coordinates (1,0), (1,1), (1,2), (1,3), (1,4), etc. to (1,30); * the third row, coordinates (2,0), (2,1), (2,2), (2,3), (2,4), etc. to (2,30); and so on, up to the sixteenth row, coordinates (16,0), (16,1), (16,2), (16,3), (16,4), etc. to (16,30).   After class has completed the hands-on procedure:  Explain why NASA needs elevation data from Mars, and how MOLA operates, or have teams go on-line and research MOLA and report back.  If you have had students create sections of Valles Marineris and Olympus Mons as the Challenge landscapes, assemble them and enjoy the view! |
| **ELABORATION:**  ***Expand/Adapt/Connect***  MOLA's laser will fire infrared pulses every ten seconds. These pulses of energy travel at the speed of light (186,000 miles per second). NASA scientists can determine the distance from the spacecraft to the land form below by timing how long it takes the pulse to travel from the spacecraft to the surface and back to the spacecraft (which you can think of as a kind of echo). Distance = Speed x Time (e.g., travel at 50 miles per hour for 3 hours and you have gone a distance of 150 miles.) If we divide this distance by 2, we have the distance from the spacecraft to the ground.  Teachers of older students might have them calibrate their measuring rods in seconds instead of length. Then, remind students of the velocity of light and have them calculate the distances to the various points in their topographical models. As a starter, MGS's orbit is X kilometers (go on-line and find out...) above Mars. Given that the standard shoe box is Y centimeters high (measure one), and that the base of the box can be considered Mars' datum (see above) then each cm on the Altimeter represents Z seconds (here's the math challenge!)  Research how laser altimeters operate and report to class. Construct a visual (poster, 3-D mock-up, etc.) to use in your report.  Research the use of sonar in other technologies and in the animal kingdom (dolphins, whales, bats).  **Adapting this Activity to Higher or Lower Grades**  Younger students may find this Activity still works well with arbitrary landforms, rather than those modeled on actual Martian topography. In this case, simply have each team create an interesting mountain/valley shape, which then becomes the challenge for other teams to survey and represent.  For a sturdy model which you'll be able to use multiple times, create the surface by crumpling newspaper and covering it with aluminum foil. Pour plaster of paris or apply papier mache over the foil, and spread the plaster all the way to the box sides to anchor the surface. It's best to have 1-3 "mountains" or one complex feature in each box; try to make the highest and lowest points about 10 cm different in length. |
| **EVALUATION:**  Look at the Challenge and Result profiles. Ask students to determine which "Result" corresponds to which "Challenge."  Suggested discussion questions:   How could a more detailed map of the surface be made? (more holes, holes closer together, thinner probes)   Where else could this map-making technique be used? (other planets and their moons, ocean floors, remote areas that are difficult to reach physically.)   What other techniques beside lasers could be used? (e.g. radar-as on NASA's Magellan spacecraft which surveyed Venus, or sonar, as in submarines.)   In what ways will future Mars Missions use MOLA information?  4. Locate a topographical map of your area: what is the scale? What symbols are used?  5. Invite a Surveyor (perhaps a student's parent) to class: What tools do they use? Do they ever work with GPS (Global Positioning Satellite) which now provides altitude data, as well as latitude and longitude?  6. Record in Mission Logbooks successes or problems in completing this Activity. |